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School of Materials

The Effect of Boundary Conditions on the Ballistic Performance of Textile Fabrics

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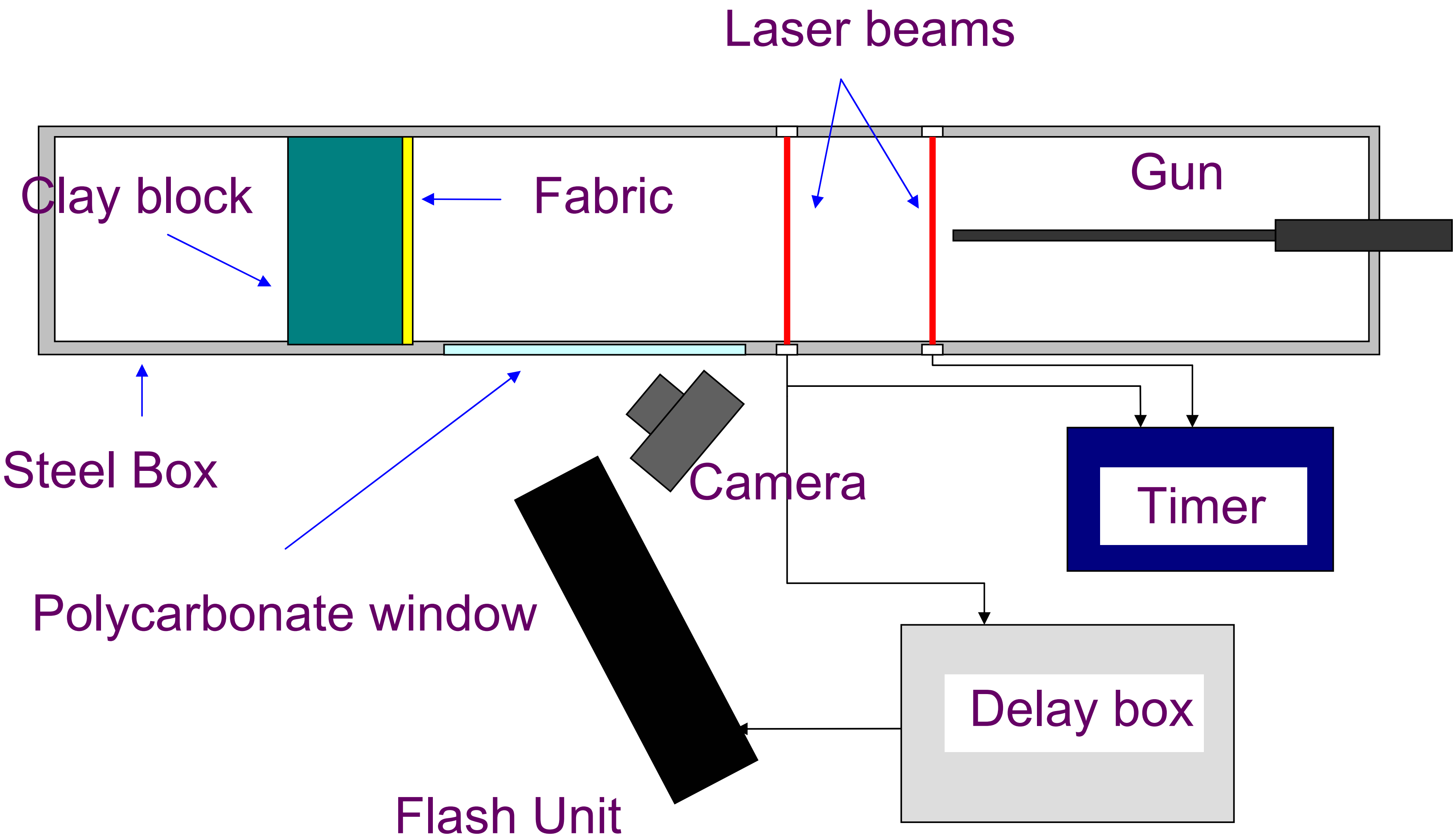
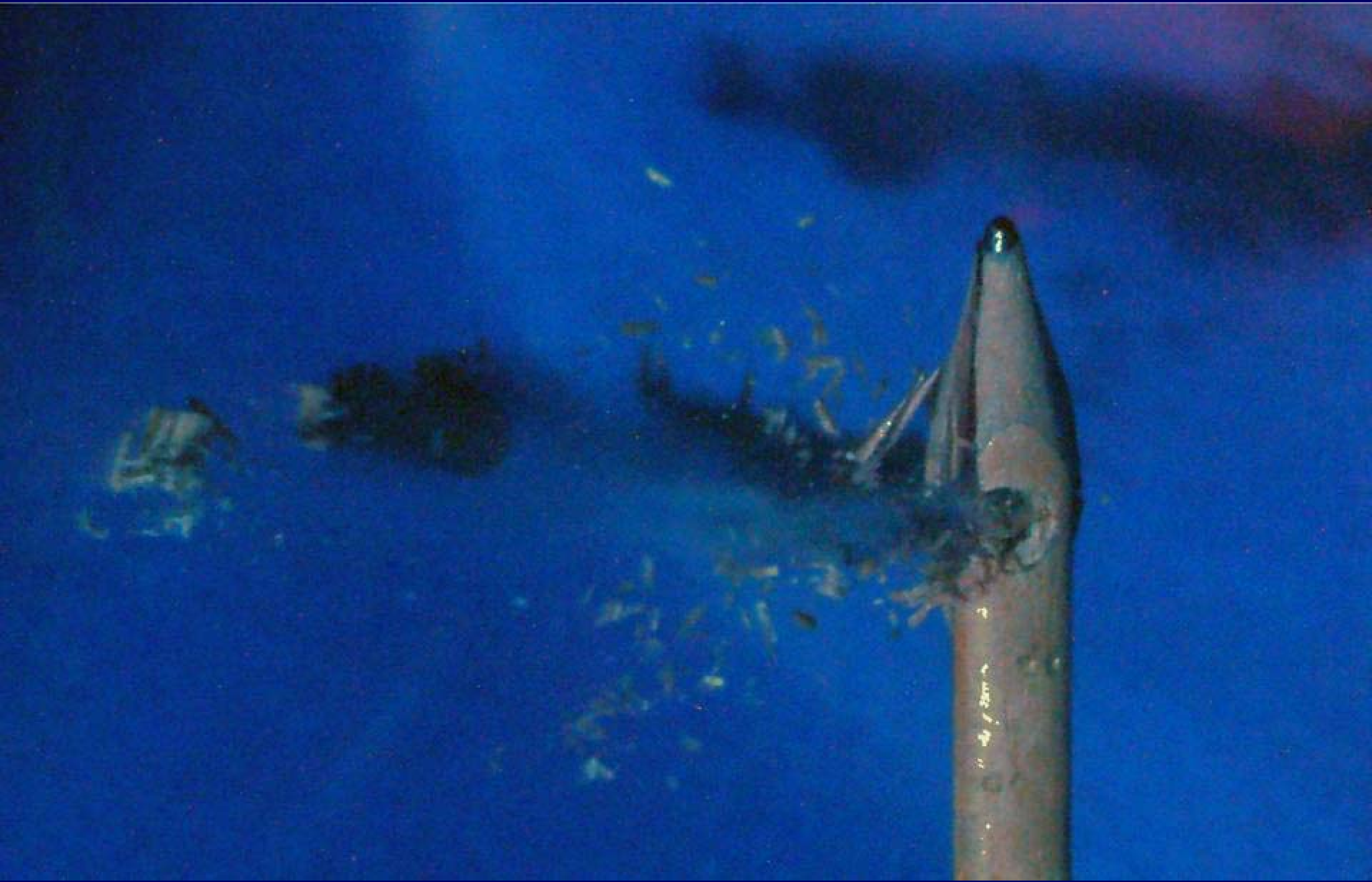
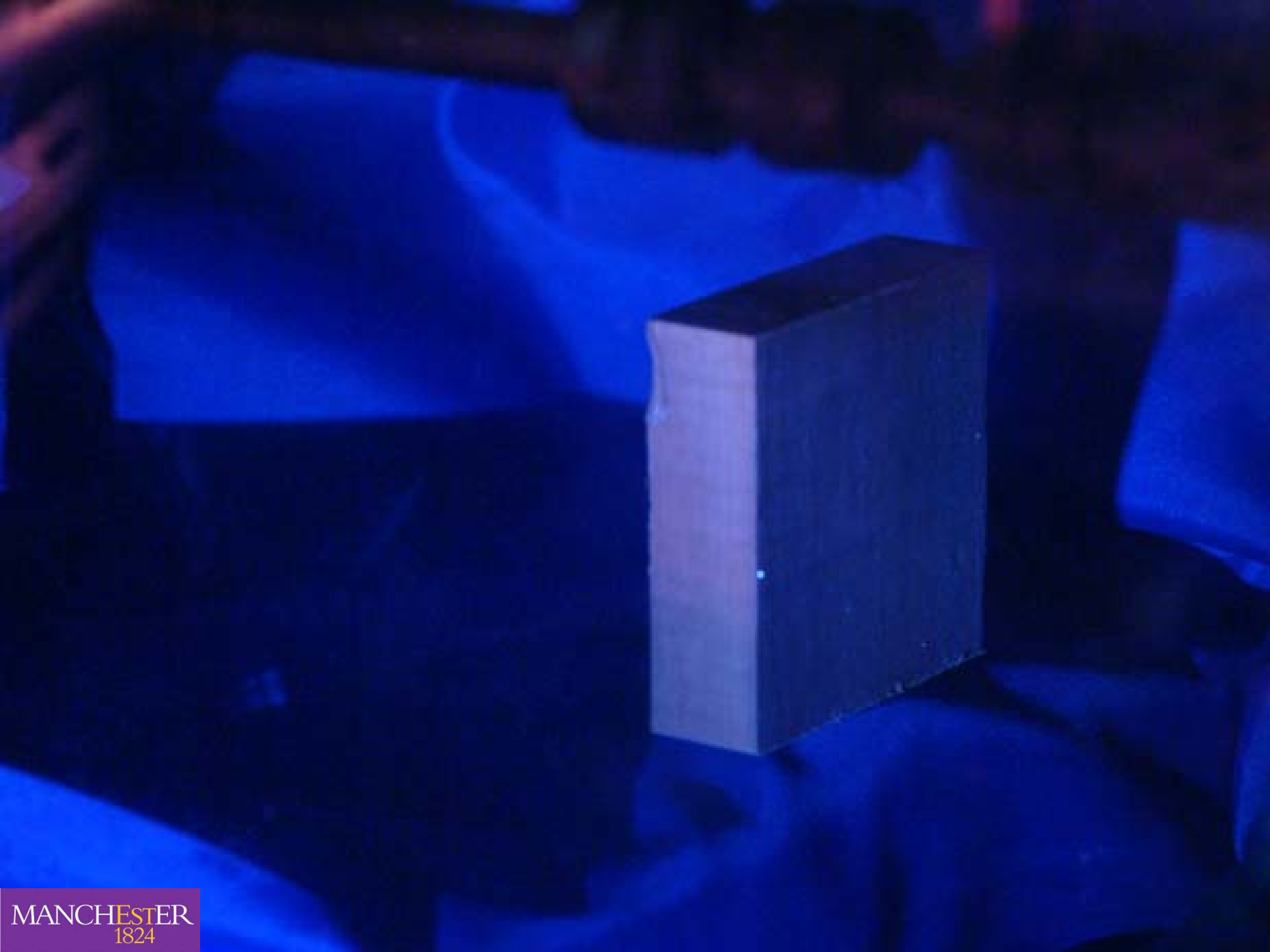


Laser beams
Clay block
Fabric
Gun
Steel Box
Camera
Timer
Polycarbonate window
Delay box
Flash Unit

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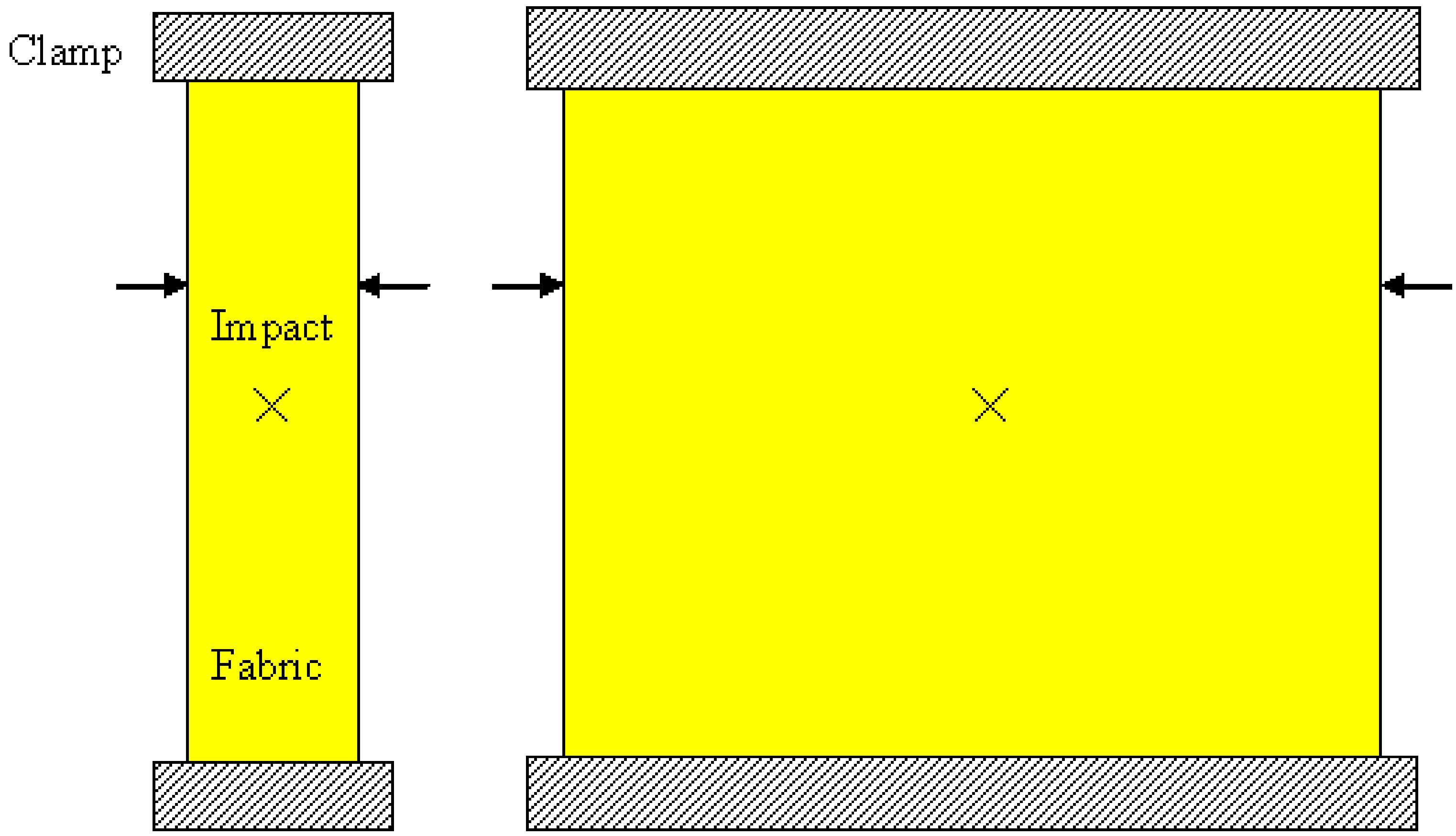
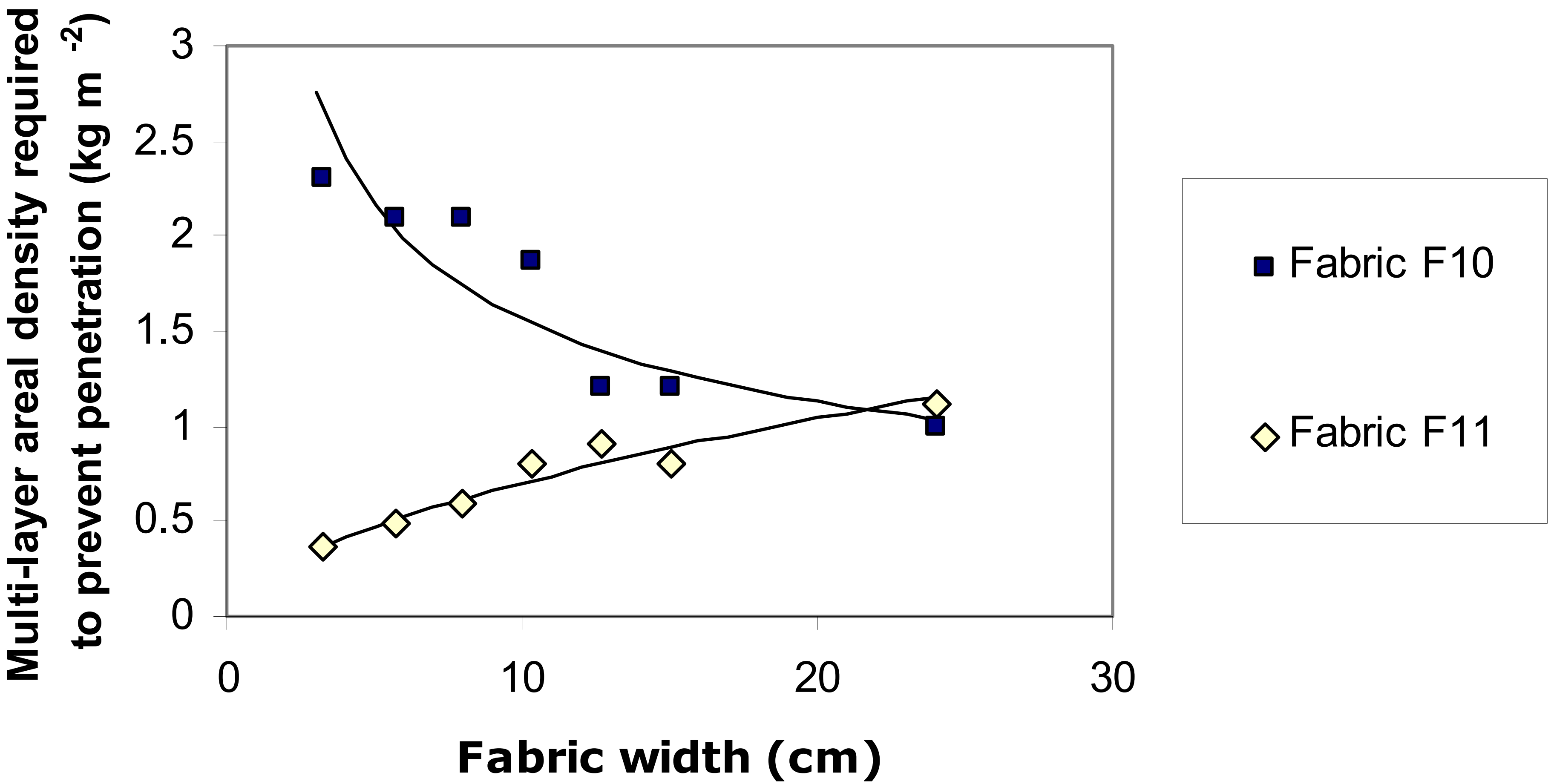
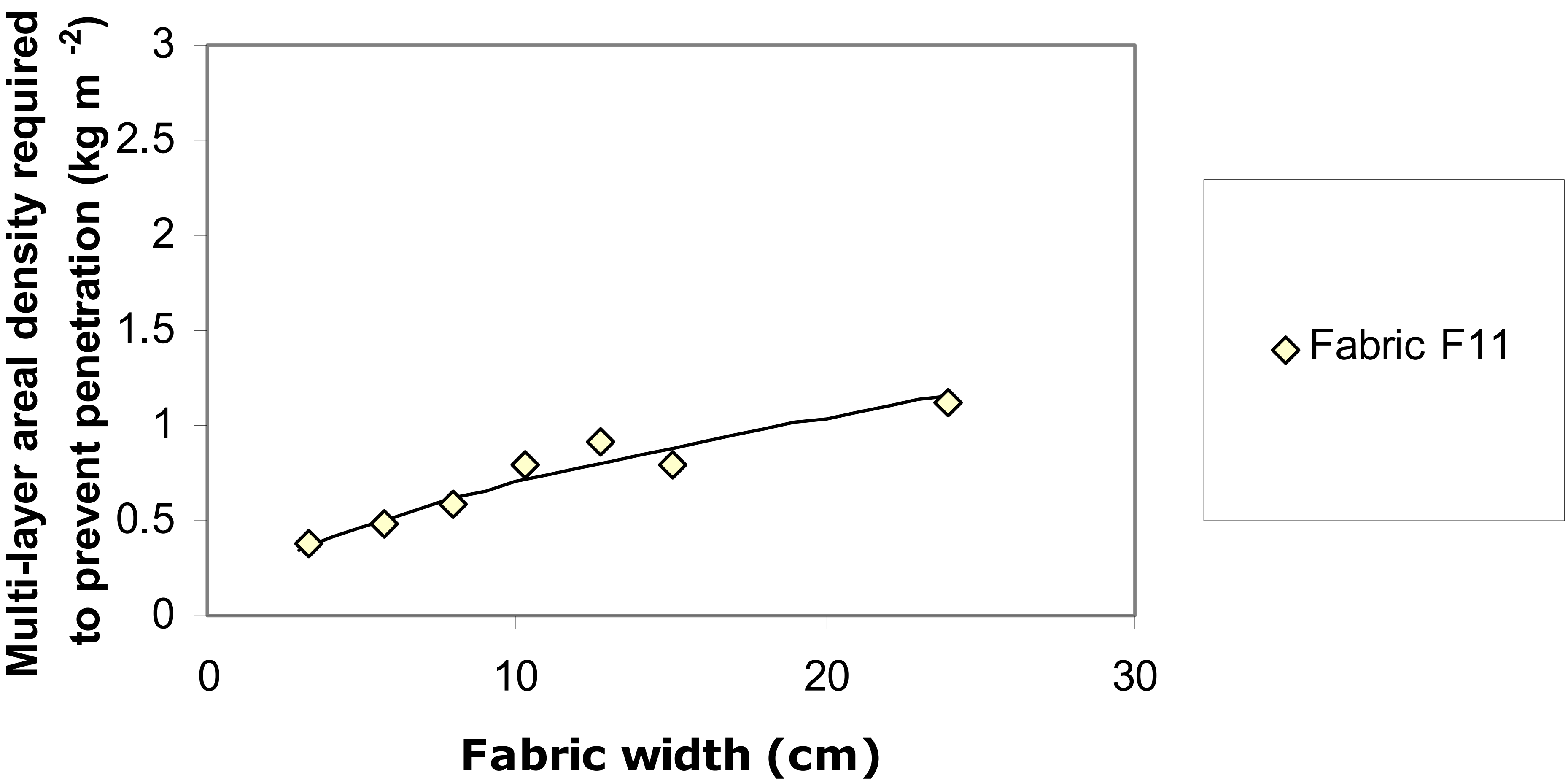
http://www.btinternet.com/~warship/Today/wave.htm


Clamp
Impact
Fabric



Weight of fabric required to prevent penetration vs. width of fabric strip.

	Fibre	Thread Density Picks/ cm	Ends/ cm	Linear density of yarn Weft (tex)	Warp (tex)	Structure
F10	Kevlar 129	6.7	6.63	167	167	Plain weave
F11	Kevlar 49	22.4	22.4	23	23	Plain weave

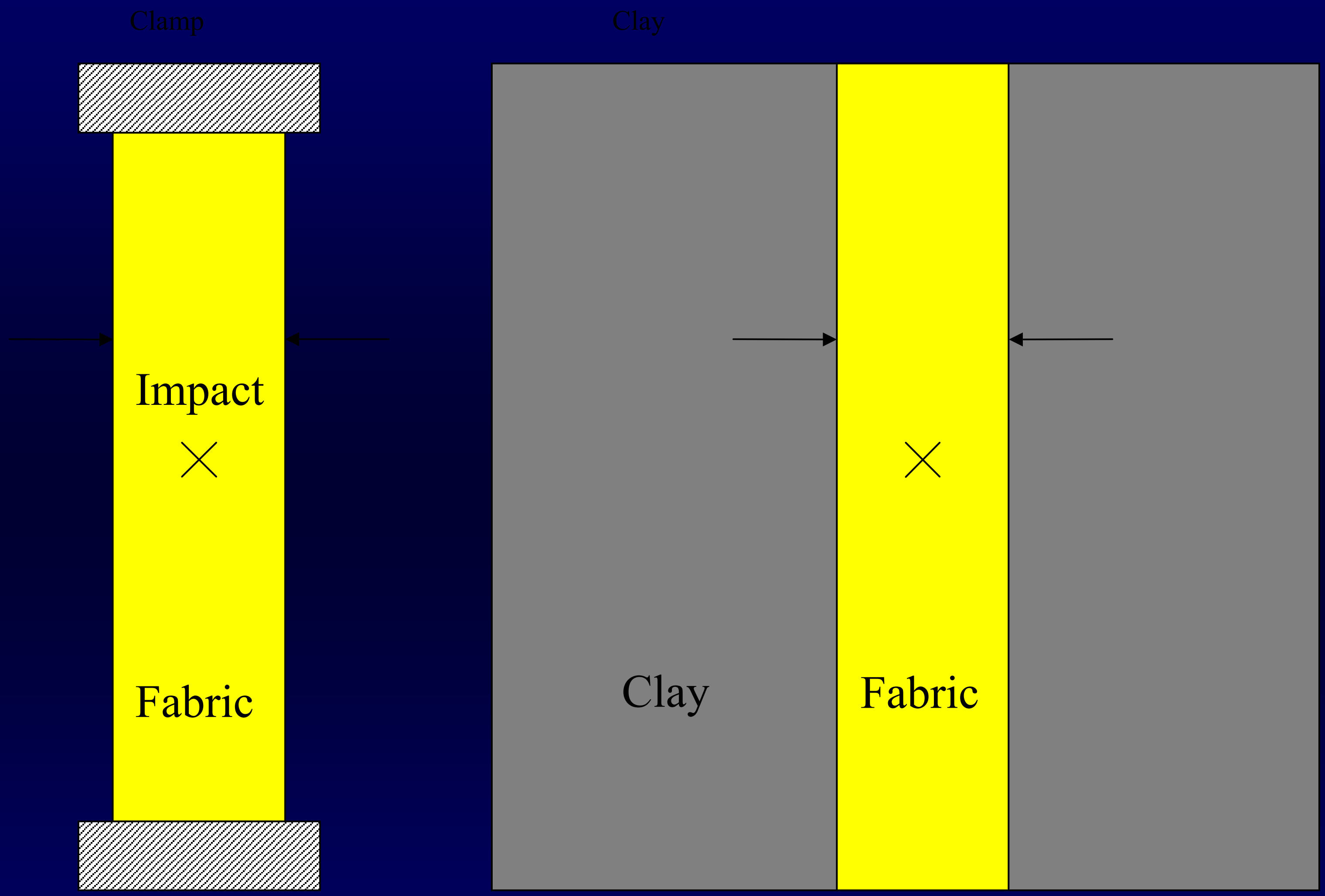


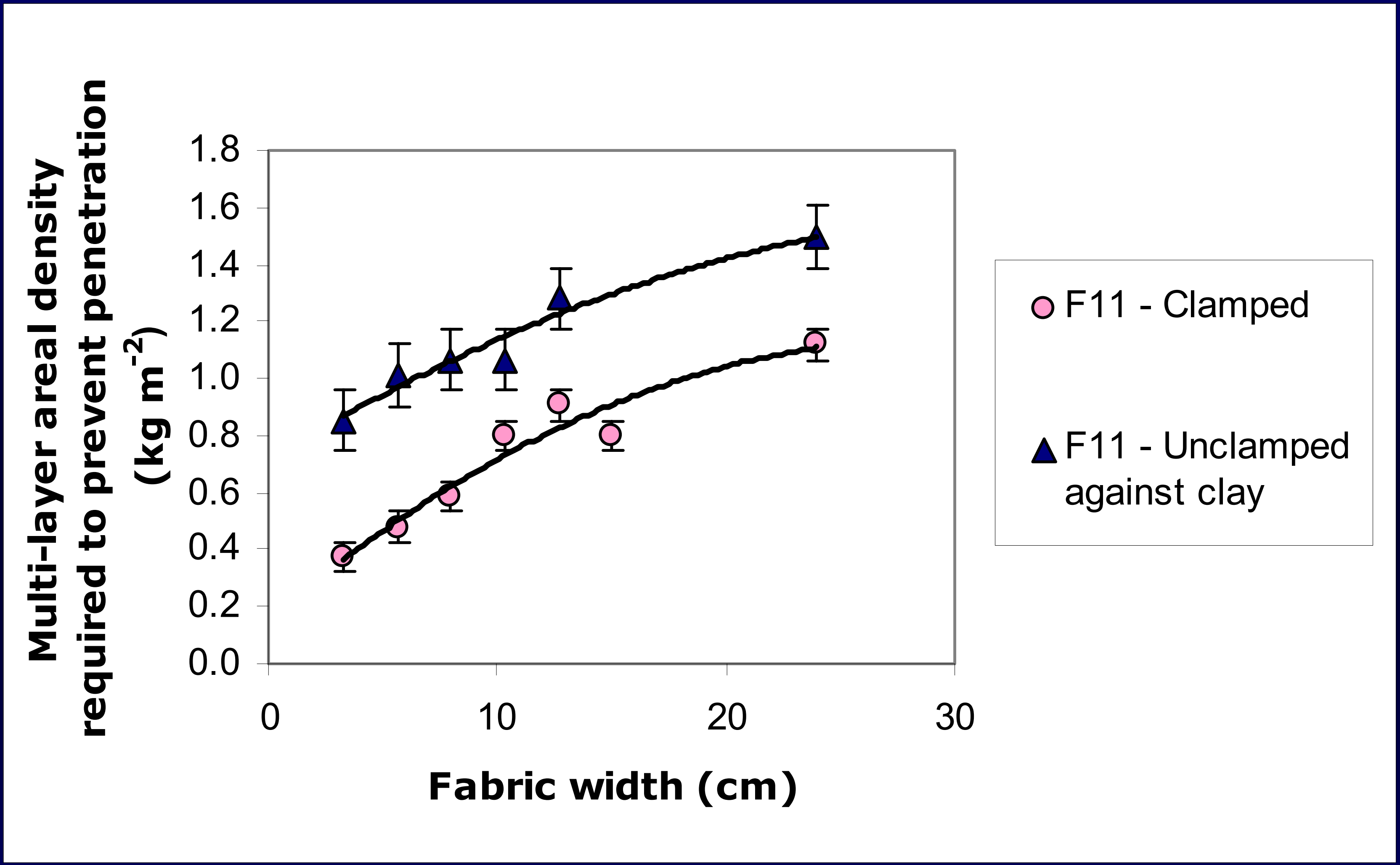
Weight of fabric required to prevent penetration vs. width of fabric strip

Width of strip	Weight of fabric required to prevent penetration
(cm)	(kg/sq m)
24	1.12
3.3	0.37

Weight saving (%)	67

Example of the effect of reducing fabric width for direct impact onto a clamped narrow fabric.


Clamp
Clay
Impact
Fabric
Clay
Fabric



Weight of fabric required to prevent penetration vs. width of fabric strip

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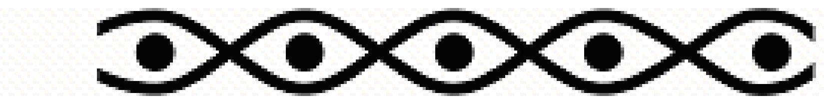
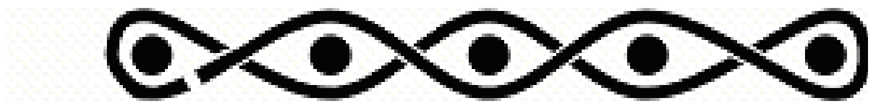
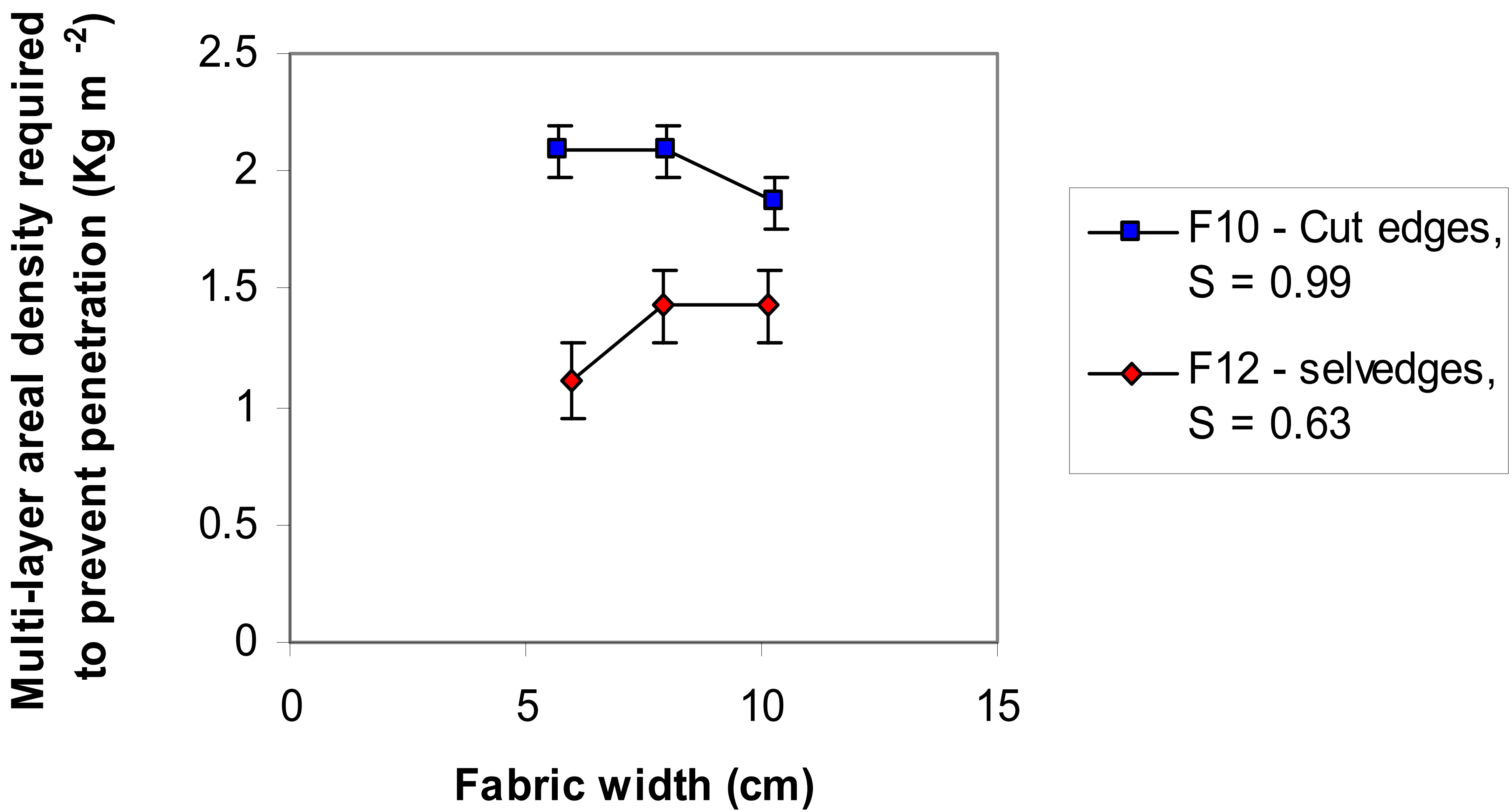


a) cut edges



b) conventional selvedges

Schematic of cross-section through narrow fabrics



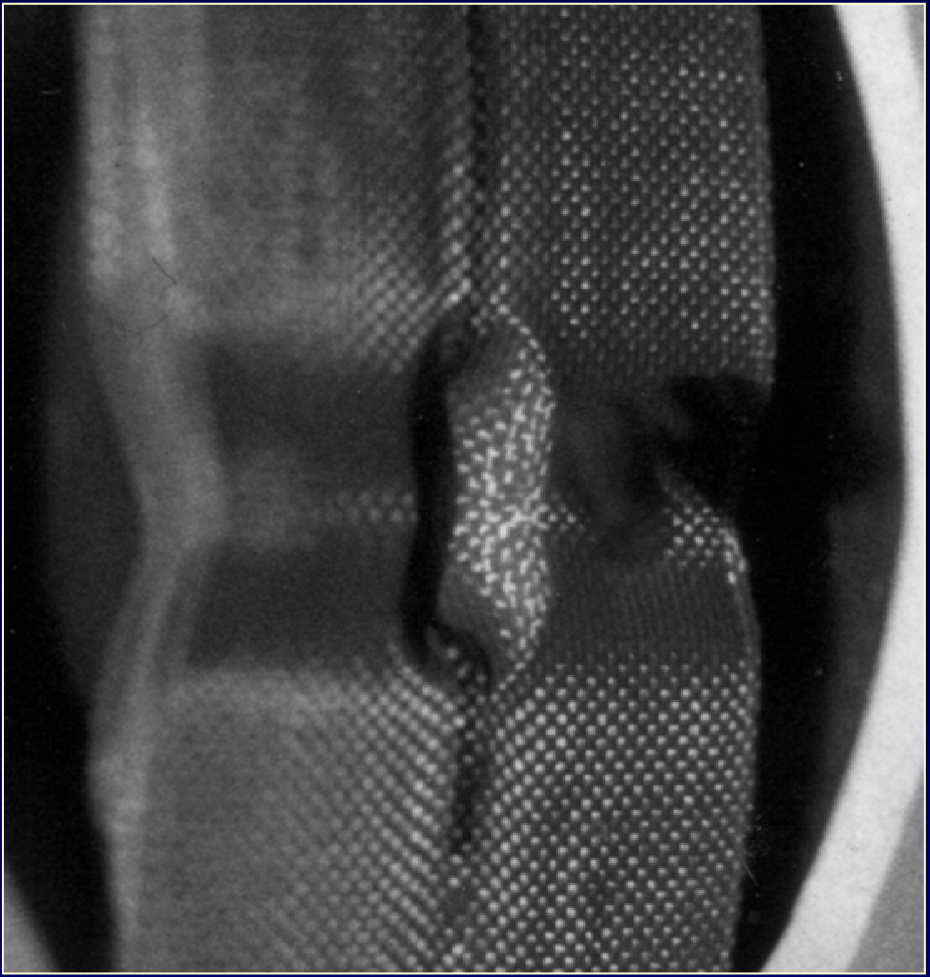
Weight of fabric required to prevent penetration vs. width of fabric strip

Mechanics of impact. Initially narrow fabric deformations are similar to those found for a regular fabric panel.

Regular fabric panel

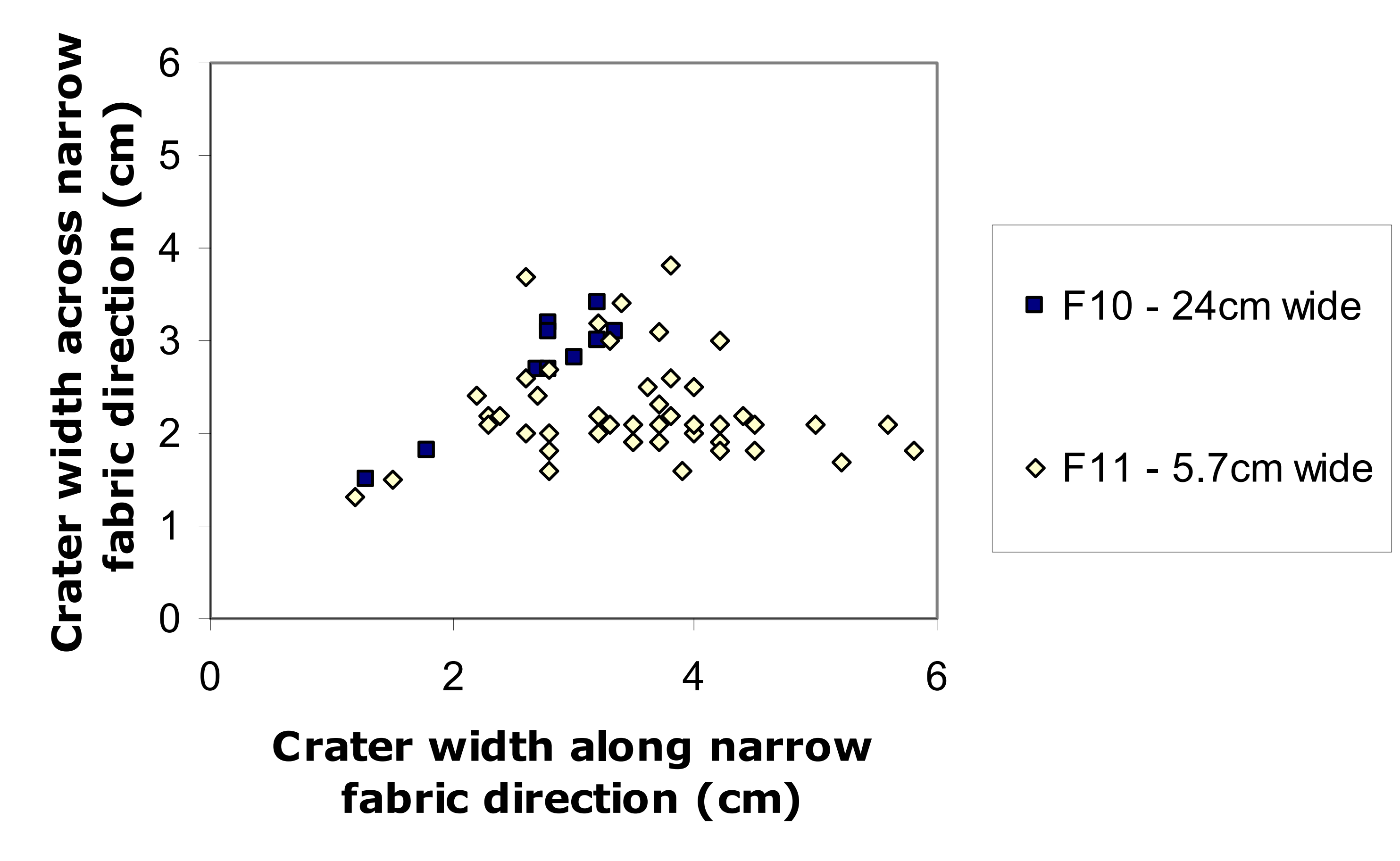
Narrow fabric

Later, in the case of narrow fabrics, deformation extends further in a direction parallel to the long sides. Typically, a peanut shaped deformation is observed.



This is reflected in the residual deformations.

Analysis of dimensions of crater left in clay



Comparison of crater widths in the two fabric directions

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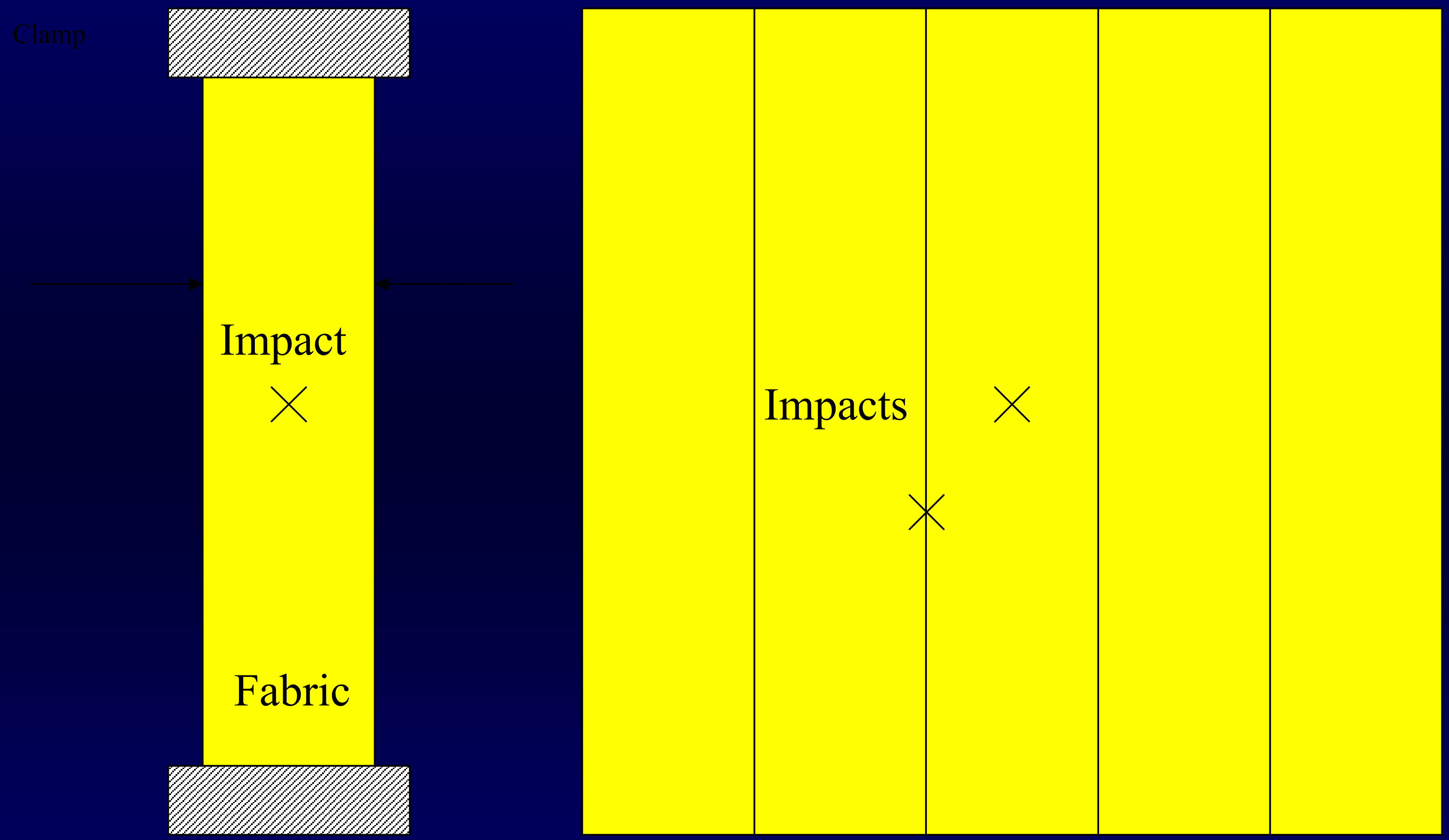
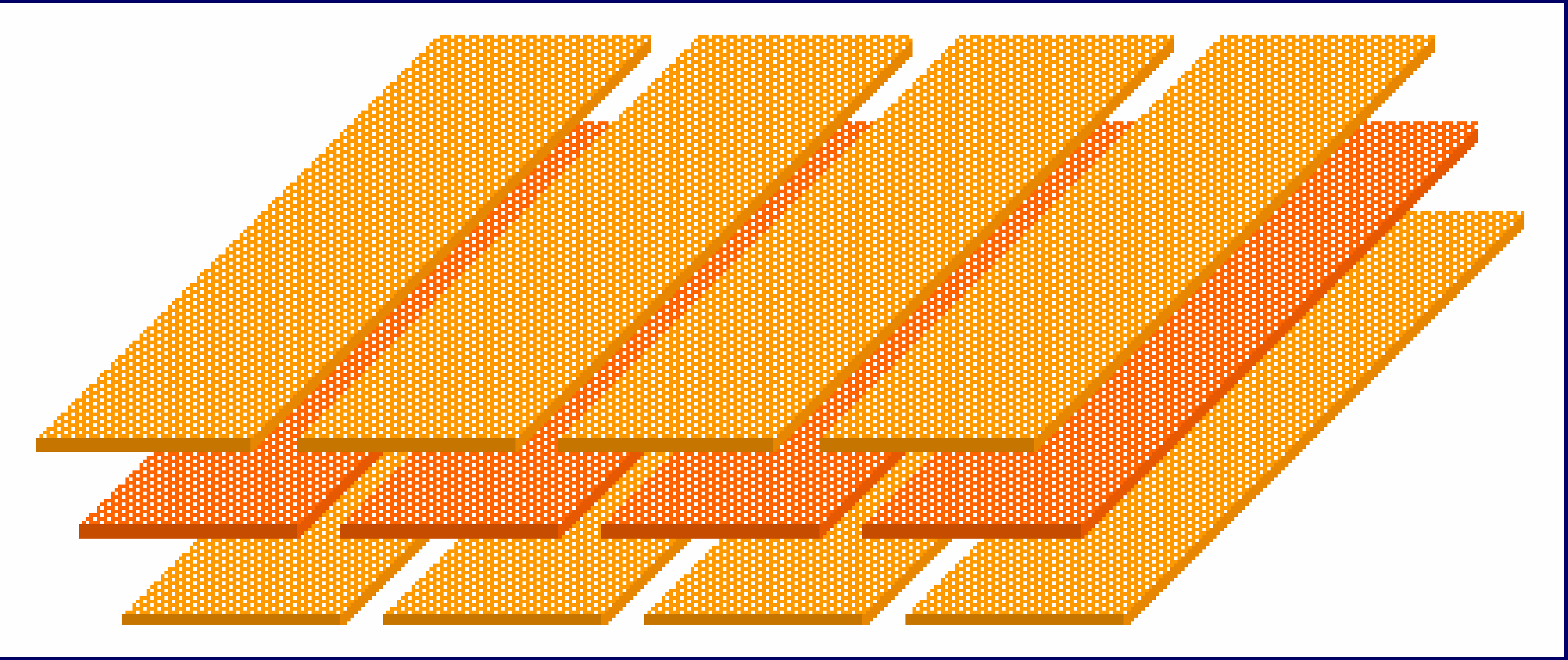
There are two problems in making practicable armour from narrow fabrics:

Impact

1. The weakness of the joins between fabric strips.
2. The weight and stiffness of any structure for holding the fabric on two sides.


Clamp
Impact
Fabric
Impacts

Joins



Narrow fabrics can be offset in different layers but the joins still contribute to an overall weakening of the fabric panel

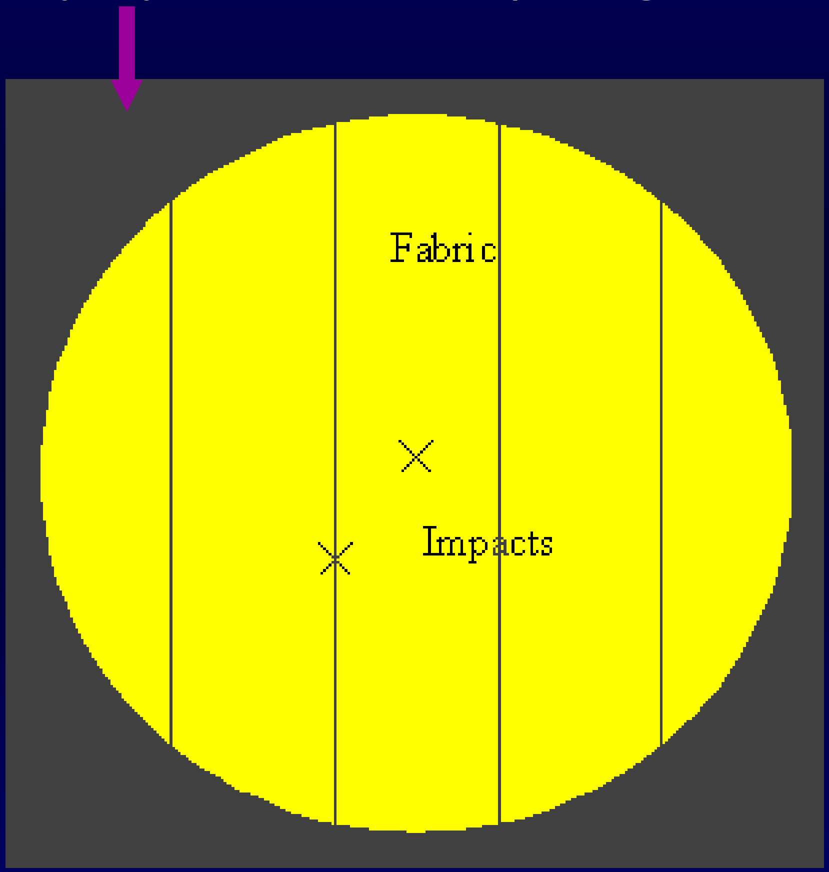
Holding the fabric

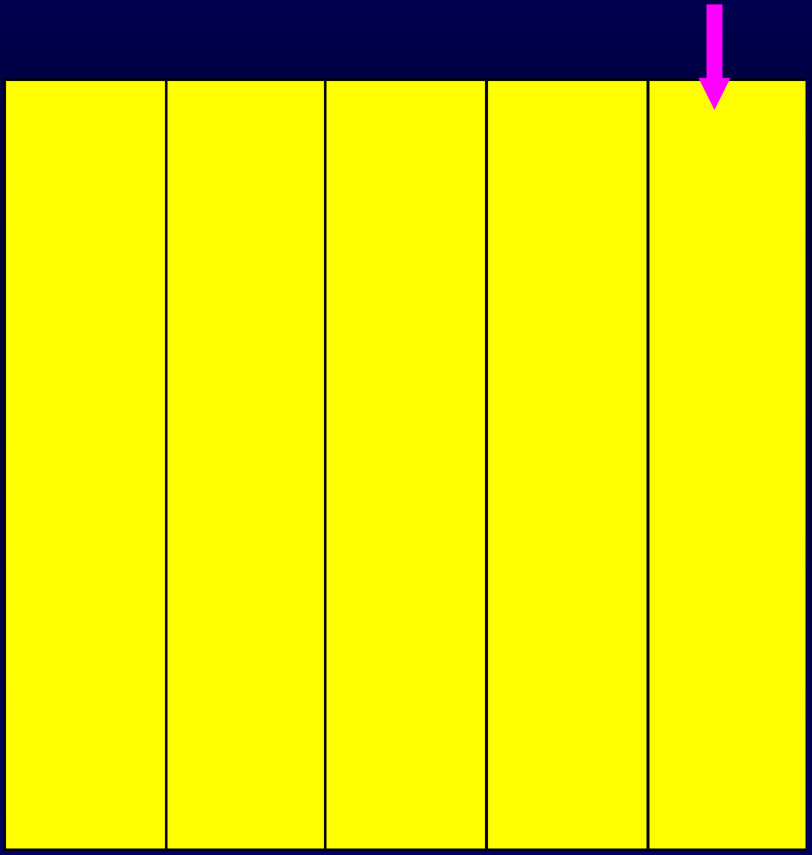
Various structures for holding the fabrics were investigated but were eliminated, either because of weight, because the grip was insufficient, or because they were destroyed by impact.

The solution was to use expanded polystyrene board.
The fabric strips were simply glued along the short sides

Polystyrene board (Weight = 28g)

Glued edge





Face and back of the armour panel.

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Impacted samples

Crater Depth in clay backing

Not only must armour arrest a projectile, but it must do it without excessive deformations. For example, it is of no use stopping a projectile if it takes a metre to do so.

Crater Depth in clay backing

	Crater Depth (cm)	Standard deviation (cm)
Benchmark (Fabric F10)	1.6	0.6
Narrow fabric assembly (Fabric F11)	1.4	0.2

Crater depth for narrow and benchmark fabric of equal areal densities.

Performance of narrow fabric assemblies

Multi-layer areal density required to prevent penetration

Impact velocity	**Benchmark - Fabric F10**	**Narrow fabric assembly - Fabric F11**	**Weight reduction**
($m\ s^{-1}$)	**($kg\ m^{-2}$)**	**($kg\ m^{-2}$)**	**(%)**
400	1.6	1.1	31
520	3.4	3.2	6

Weight saving - Narrow fabric panel compared to control fabric. Results based on weight of **whole assembly.**

Performance of narrow fabric assemblies

Multi-layer areal density required to prevent penetration

Impact velocity	**Benchmark Fabric F10**	**Narrow fabric assembly - Fabric F11**	**Weight reduction**
($m\ s^{-1}$)	**($kg\ m^{-2}$)**	**($kg\ m^{-2}$)**	**(%)**
400	1.6	0.6	63
520	3.4	2.6	24

Weight saving - Narrow fabric panel compared to control fabric. Results based on weight of **fabric alone**.

What we do not know about narrow fabrics

The minimum forces required to grip the fabrics (Can the weight of a soldier's equipment be utilised to hold the narrow fabrics under tension?)

The weave/width combination required to maximise ballistic performance.

The selvedge construction required to maximise ballistic performance.

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What we **do not know** about narrow fabrics (Continued)

The fibre properties required to maximise the ballistic performance (Should they be different in warp and weft).

The frictional properties of yarns required to maximise the ballistic performance.

The relationship between ballistic performance and fabric length.

The relationship between ballistic performance and impact velocity.

What we **know** about narrow fabrics

The deformations of narrow fabrics undergoing ballistic impact differ to those for regular fabrics.

With the appropriate choice of narrow fabric construction, width, selvedge and method of gripping significant improvements in ballistic performance can be achieved.

Incorporating narrow fabrics into ballistic panels results in improvements in performance-to-weight ratios despite the weaknesses introduced by fabric joins.

Where some existing structure is present, such as an aircraft fuselage, still greater performance-to-weight ratios can be achieved.

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THE END